ECORCE AS AN INTERNATIONAL PAVEMENT LCA TOOL: A STUDY OF ADAPTATIONS REQUIRED FOR APPLICATION IN DIFFERENT COUNTRIES

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ABSTRACT

ECORCE is a streamlined pavement LCA tool developed in France for free distribution. Its environmental data come from public databases adapted to the French context and from onsite measurements. Given that materials used in road construction are for the most part produced locally, the environmental database must be adapted for the region for which it is to be used. This joint Québec-France study starts by identifying differences in unit indicators from various international environmental sources. The most widely used processes in pavement LCA were investigated in order to adapt the database for use in Québec. Although numerous pollutants are considered in LCI (several hundred can be found in the literature), only a few are usually significant contributors to impact indicators. From a mathematical standpoint, pollutant contributions depend on the list of pollutants and their classification and characterization factors. A contribution analysis was conducted to identify the most important processes and pollutants for the different impact indicators available in the tool, and to highlight critical aspects of the development and adaptation of the database to other countries. An analysis of *ECORCE* data was therefore conducted to identify the most important pollutants for various processes and their impacts. Results of this analysis underscore sensitive aspects to be considered in choosing a database and LCIA models in adapting a regionally relevant pavement LCA tool.

INTRODUCTION

The Life Cycle Assessment (LCA) methodology developed more than 20 years ago in the manufacturing sector allows for an in-depth evaluation of interactions between technological processes and their impacts on the environment. This methodology is based primarily on an assessment of material and energy flows between components of a system, as well as between this system and the environment. The system studied typically comprises all activities associated with a given product or service, from raw material extraction to waste disposal. The potential impacts of such activities on the environment are then assessed based on the calculated flows and life cycle impact assessment (LCIA) models. This method has been described in the ISO 14040 and 14044 standards *(1,2)*.

ECORCE (ECO-comparator applied to Road Construction and Maintenance) is a streamlined LCA tool. Its 2.0 version was developed by Ifsttar (French Institute of Science and Technology for Transport, Spatial Planning, Development and Networks) in 2013 *(3)*. Data related to pavement infrastructures are input into the tool, which outputs information on resource use and six environmental impacts.

The environmental database and LCIA models selected are relevant to the French pavement context. For the tool to be used in other countries, some of these methodological choices must be modified. Before integrating the results of this type of tool in a decision making process, it is important to ensure that the results are not biased by the choice of databases and LCIA models. A preliminary analysis of the data and their influence on the results must be achieved.

The Ministère des Transports du Québec (Quebec Transportation Department, MTQ) has an interest in environmental evaluation of road construction and maintenance. Collaboration with Ifsttar was initiated a few years ago to identify the most significant aspects to consider in adapting the tool *(4)*. The method tested with *ECORCE* data for this adaptation is described in this paper.

The main principles underlying the *ECORCE* methodological choices are first described. Unit indicators from different sources are then compared to highlight the influence of life cycle inventory (LCI) data on impact indicators. Finally, results of a contribution analysis conducted with *ECORCE* data to identify the most important pollutants and analyze the equivalence of processes in different databases are presented.

GENERAL PRESENTATION OF *ECORCE*

The *ECORCE* interface was developed for civil engineering users. A multilayer approach was selected to define the road structure to be studied. The tool calculates process quantities from pavement design, construction and maintenance operations specified by the user. These processes are converted into six environmental impacts using classification and characterization factors for the related pollutants.

The principle underlying this software is to provide an executable file and related yet separate database that can be modified using a utility tool. The database can only be modified as part of a deliberate action by the user. The *ECORCE* software uses public road construction industry data relevant to the French context.

Unlike typical civil engineering practices related to experimental validation in the field, *ECORCE* results may not be validated; comparative approaches must therefore be used. Result quality depends entirely on the quality of available environmental data.

System Boundaries and Data Sources

Version 2.0 of *ECORCE* involves a homogeneous environmental system in terms of boundaries relative to upstream processes; this is particularly true for energy production, the indirect impacts of which must also be factored in. The environmental system used in this tool is not explicitly defined by the user for each case study since it is already defined in a global way. This system includes all limitations associated with the following processes:

- Material production within industries (refineries, cement works, quarries, lime kilns and steel mills);
- Production and storage of non-hazardous wastes that may be reused as materials in road infrastructure (data treated as part of the OFRIR 2 project (French Observatory of Resources for Infrastructures), a web platform that shares data on construction materials) *(5)*;
- Materials and worksite machinery transportation;
- Mix production (asphalt mixing plants, concrete plants, etc.);
- Pavement construction, maintenance and earthworks activities (fuel consumption of worksite vehicles, including demolition machinery).

The pollutant list in *ECORCE* is derived from previous studies (e.g. concrete plant) *(6)*, public databases (e.g. cement, bitumen, steel, polymer, acid, lime) and from onsite studies conducted by Ifsttar (e.g. equipment operation, asphalt plant, aggregate production, recycled aggregates), whereas energy production data are taken from the FD P01-015 standard *(7)*. Infrastructure and equipment manufacture are excluded from system boundaries. The public databases contain hundreds of pollutants derived from average production conditions. The onsite measurements are context-specific but for a very restricted list of pollutants. For these processes, all other pollutants come from the energy production database. Data collected by Ifsttar were presented in papers submitted to international journals in conjunction with *ECORCE* development process. These data were validated through the standard journal review process (including at least 2 anonymous reviewers) and PhD committee members who also provided scientific assessment of work performed on the environmental data uploaded in *ECORCE*. A list of processes, a description of system boundaries, and database sources are presented in the reference manual *(8)*.

Calculation of Impact Indicators

The environmental impact assessment is conducted using classification and characterization factors. An equi-probable classification is used, as described in Ventura 2011 *(9)*. For each process, a unit indicator is calculated as follows:

$$UI_i = \sum A_{pi} = \sum \left(m_p \times CF_{pi} \times CC_{pi} \right) \tag{1}$$

where:

UI_i is the unit indicator of impact i

A_{pi} is the contribution of pollutant p to the unit indicator of impact i

m_p is the mass of pollutant p

CF_{pi} is the characterization factor of pollutant p for impact i

CC_{pi} is the classification coefficient of pollutant p for impact i

All characterization factors and classification coefficients are reported for each impact indicator in the reference manual *(8)*. The characterization factors are taken from CML methodology following recommendations from Guinée 2002 *(10)* except for global warming potential (GWP) that come from IPCC 2007 *(11)* and for photochemical ozone creation potential (POCP) that come from French standard NF P01-010 *(12)*. Calculations by *ECORCE* are based on indicators taken from the scientific literature. Some of the indicators selected in *ECORCE* 2.0 have wide international acceptance, while others are the subject of ongoing debate within the scientific community.

Time is not explicitly included into environmental calculations through pollutant emission time increments; it is rather indirectly accounted for through discrete maintenance operations, as well as through pollutant classification coefficients in impact categories that sometimes integrate the concept of persistence.

SENSITIVITY ANALYSIS OF UNIT INDICATORS

Only some of the processes included in *ECORCE* are addressed in this paper. The main processes common to pavement practices in most countries are related to bitumen, cement, aggregates and steel production, transportation, equipment, and concrete and asphalt plants. These well-documented processes also highlight the regional and technological variability of environmental databases. Various factors affect the production of materials such as bitumen, cement, steel and aggregates, including electricity grid mix, fuel types used and infrastructure performance, which can vary significantly among regions. Moreover, different allocation procedures for co-products and by-products can also induce significant differences. Figure 1 shows energy consumption indicators from five different sources for the production of one tonne of each of six processes. This indicator being a LCI output without characterization factor illustrates well the variability in databases. Data sources are shown in Table 1.

Table 1: Indicator Sources

Identification		Country	Reference Description
1	*ECORCE* v2.0 *(3, 8)*	France	Pavement LCA tool
2	Athena 2006 *(13)*	Canada	Pavement LCA report for Portland Cement Association
3	Cimbéton 2001 *(14)*	France	2005 Pavement LCA report by Cimbéton updated in 2011
4	Chapat & Bilal 2003 *(15)*	France	Pavement LCA report by COLAS (road contractor)
5	Weiland 2010 *(16)*	USA	Pavement LCA report in USA

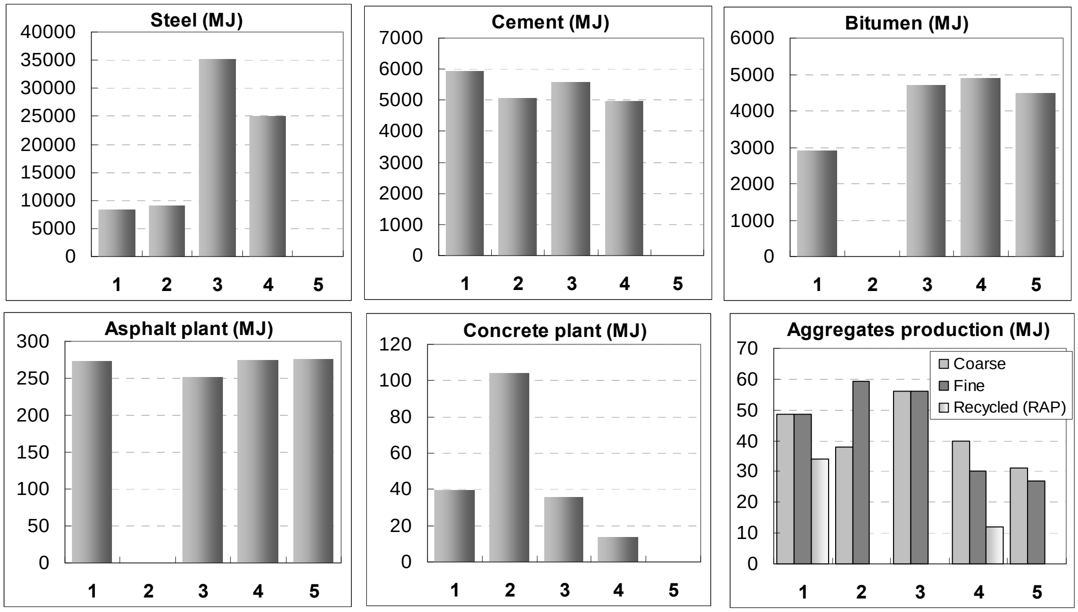

Figure 1: Comparison of energy indicators from various sources, for the production of one tonne of material.

As shown in Figure 1, energy consumption indicators from different sources can differ by a factor of 10 to 500%. An important factor contributing to this variability is the fact that system boundaries differ from one source to the next. This highlights the importance, in adapting an LCA tool such as *ECORCE*, of basing the choice of data sources on an analysis of many different aspects. In addition to being relevant to the regional and technological context, the database as a whole must be coherent and have consistent system boundaries.

ASSESSMENT OF POLLUTANT CONTRIBUTIONS

This part of the study was initiated to identify data that are incomplete or likely to vary regionally. It is important to understand the impact of missing or aggregated data on results. In many cases, although there may be hundreds of pollutants with a characterization factor for a given impact indicator, only a few may contribute to it in a significant way. The first step consisted therefore in identifying those pollutants in the *ECORCE* database that were the main contributors to various impact indicators. To this end, all pollutants were extracted from *ECORCE* for analysis.

Methodology

A first threshold was set as follows: for each impact indicator, the sum of the selected pollutants must represent at least 97% of all contributions for the indicator. The other pollutants are summed in a category called "Others".

A second threshold was set as follows: pollutants that represent at least 10% of indicator values for at least one process were identified. The number of pollutants contributing to each impact indicator, the number of pollutants representing at least 97% of these indicators and the number of pollutants representing 10% or more of indicator values for at least one process are reported in Table 2. This short list was examined more closely to ascertain that no important contributor was overlooked for any of the processes.

Table 2: Number of Significant Pollutants for the 6 Impact Indicators in *ECORCE*

Impact	No. of Pollutants	No. of Pollutants (Σ A ≥ 97%)	No. of Contributors > 10%
Global Warming Potential (GWP)	20	4	3
Acidification Potential (AP)	3	3	2
Eutrophication Indicator (EI)	15	15	7
Photochemical Ozone Creation Potential (POCP)	91	8	6
Toxicity Potential (TP)	169	32	15
Ecotoxicity Potential (EP)	164	22	9

Table 2 shows that, for all the processes in the *ECORCE* database, 2 to 15 pollutants can account for more than 10% of the value of an impact indicator. These pollutants are identified in Table 3. Obviously, after this step, the contribution of "Other" pollutants can be more important. The contribution of these pollutants to the six unit impact indicators for seven processes in *ECORCE* are also reported in the table. Values in bold are significant pollutants which account for 10% or more of the impact indicator. Values set to 0.0% indicate that data are available for the pollutant but that its contribution is nil or less than 0.0%. Cells with no number represent missing data and hatched cells represent potentially important contributors for which data are missing.

Table 3: Contribution of Significant Pollutants to the 6 Impact Indicators for 7 Processes in *ECORCE*

	Charac. Factor	Class. Factor	Steel	Bitumen	Cement	Aggregates	Concrete Plant	Asphalt Plant	Machinery & Transport
Global Warming Potential (GWP)									
air CO_2	0.01	1	**93.6%**	**90.9%**	**98.2%**	**68.6%**	**99.2%**	**96.0%**	**92.9%**
air N_2O	298	1	1.1%	0.8%	0.6%	**27.0%**	0.6%	0.2%	3.6%
air CH_4	0.25	1	4.0%	7.8%	0.9%	2.8%	0.0%	3.0%	3.1%
Others			*1.3%*	*0.5%*	*0.3%*	*1.6%*	*0.2%*	*0.7%*	*0.4%*
Acidification Potential (AP)									
air SO_x	1.2	0.33	**82.7%**	**70.8%**	**51.8%**	**14.2%**	**11.9%**	**80.9%**	7.9%
air NO_x	0.5	0.33	**17.3%**	**29.2%**	**41.8%**	**85.7%**	**88.1%**	**19.1%**	**92.1%**
air NH_3	1.6	0.5	-	0.0%	6.4%	0.1%	-	0.0%	0.0%
Eutrophication Indicator (EI)									
aq NH_3, NH_4^+	0.35	1	**16.8%**	0.1%	1.0%	-	-	-	-
aq P	3.06	1	**18.2%**	**24.7%**	2.7%	0.0%	-	0.3%	0.0%
aq COD[1]	0.022	1	0.3%	**12.7%**	0.6%	0.0%	0.1%	0.6%	0.2%
air NH_3	0.35	0.5	-	0.1%	**10.2%**	0.1%	-	0.0%	0.0%
aq N	0.42	1	1.5%	1.6%	0.4%	1.5%	0.3%	9.0%	5.4%
air N_2O	0.27	1	6.3%	2.4%	4.9%	**19.2%**	1.5%	1.8%	6.0%
air NO_x	0.13	0.33	**56.9%**	**57.6%**	**79.7%**	**79.2%**	**98.2%**	**88.3%**	**88.4%**
Others			-	*0.9%*	*0.5%*	-	-	-	-
Photochemical Ozone Creation Potential (POCP)									
air VOC[2]	0.377	1	-	**68.2%**	0.1%	**47.7%**	**66.8%**	**31.0%**	0.0%
air HC[3] unspecified	0.377	1	-	8.2%	**16.6%**	0.0%	-	0.0%	0.0%
air SO_x	0.048	0.33	**16.7%**	6.8%	7.9%	1.2%	2.2%	4.3%	0.4%
air CO	0.027	1	**53.6%**	9.0%	**21.9%**	**13.1%**	8.0%	9.2%	4.3%
air NO_x	0.028	0.33	4.9%	3.9%	8.9%	**10.4%**	**23.0%**	1.4%	6.8%
air (NM GOC[4])	0.42	1	**22.0%**	-	**39.1%**	**27.1%**	-	**53.4%**	**88.0%**
Others			*2.8%*	*3.7%*	*5.5%*	*0.4%*	*0.0%*	*0.6%*	*0.6%*

[1] COD: Chemical oxygen demand *[2] VOC: Volatile organic compound* *[3] HC: Hydrocarbons*

[4] NM GOC: Non-methane gazeous organic compound *[5] PAH: Polycyclic aromatic hydrocarbon*

Table 3: Contribution of Significant Pollutants to the 6 Impact Indicators for 7 Processes in *ECORCE (continued)*

	Charac. Factor	Class. Factor	Steel	Bitumen	Cement	Aggregates	Concrete Plant	Asphalt Plant	Machinery & Transport
Toxicity Potential (TP)									
air dioxins	1933982792	0.5	**17.1%**	0.0%	0.0%	-	-	-	-
air HF	2851	1	-	2.2%	3.0%	-	-	-	-
aq Se freshwater	56010	1	-	6.5%	1.1%	-	-	-	-
air Zn	104.4	1	**12.4%**	0.0%	0.1%	0.0%	-	0.0%	0.0%
air Hg	6008	1	4.7%	0.2%	0.3%	0.0%	-	0.0%	0.0%
air NO_x	1.2	0.33	2.5%	2.6%	1.5%	9.5%	**92.2%**	0.5%	3.5%
air Se	47690	1	-	1.4%	0.3%	0.9%	-	0.7%	0.2%
air PAH[5]	570000	0.5	-	2.3%	5.3%	2.6%	-	2.8%	0.5%
air As	347700	1	-	**10.2%**	5.5%	5.6%	-	4.6%	1.2%
air Cd	145040	1	**52.0%**	8.7%	2.4%	1.8%	-	4.6%	1.2%
air V	6240	1	-	7.0%	3.9%	5.2%	-	**15.7%**	4.1%
air Ni	35030	1	-	**21.4%**	8.8%	7.9%	-	**22.0%**	5.8%
aq PAH freshwater	280500	1	-	**11.6%**	**12.5%**	**63.8%**	-	**48.0%**	**82.8%**
aq ethylene oxide freshwater	11430	1	-	0.0%	**16.5%**	-	-	-	-
air ethylene oxide	14070	0.5	-	0.0%	**11.4%**	-	-	-	-
Others			***11.3%***	***25.8%***	***27.3%***	*2.7%*	*7.8%*	*1.0%*	*0.7%*
Ecotoxicity Potential (EP)									
aq Phenol freshwater	324.8	1	-	0.0%	0.0%	-	**100.0%**	-	-
aq Ba freshwater	1549000	1	-	7.9%	**13.8%**	-	-	-	-
aq Be freshwater	774500000	1	-	**22.7%**	1.5%	-	-	-	-
air HF	54160000	1	-	**24.7%**	**60.9%**	-	-	-	-
air Zn	135400	1	**81.1%**	0.0%	0.1%	0.1%	-	0.0%	0.0%
air Se	30200000	1	-	0.5%	0.2%	2.4%	-	0.7%	0.6%
aq Ni freshwater	4498000	1	3.1%	8.9%	0.6%	1.1%	-	0.3%	1.4%
air Ni	7494000	1	-	2.7%	2.0%	7.4%	-	7.3%	7.2%
air V	23510000	1	-	**15.3%**	**15.6%**	**85.6%**	-	**91.0%**	**89.7%**
Others			***15.9%***	***17.3%***	*5.3%*	*3.4%*	-	*0.8%*	*1.2%*

[1] *COD: Chemical oxygen demand* [2] *VOC: Volatile organic compound* [3] *HC: Hydrocarbons*

[4] *NM GOC: Non-methane gazeous organic compound* [5] *PAH: Polycyclic aromatic hydrocarbon*

Results Analysis

Table 3 shows that cement and bitumen have the most complete LCI while data are often missing for the other processes. The onsite measurements for aggregates, asphalt plant and machinery have been completed with energy production LCI, which explains homogeneity in missing data for these processes. For concrete plant, energy was already included in Stripple 2001 *(6)*, which explains that more pollutants are missing.

No significant pollutants are missing for GWP, AP and POCP indicators. For POCP, the missing data are related to aggregation in different pollutant families. Eutrophication, toxicity and ecotoxicity are the impact indicators with more missing pollutants. Considering the very wide range in TP and EP characterization factors, small variation in pollutants quantity can have a very important influence on unit indicators. As can be seen for concrete plant, the most important contributor to each of these impact indicators is also the only important pollutant for this process, and has a very low contribution to other processes. This is due to a lack of data for concrete plants and does not reflect the real importance of these pollutants. It shows that this method is not optimal for toxicity and ecotoxicity indicators.

Highlights from Table 3 for the six impact indicators are discussed below. Figures are also presented which show unit indicator values in *ECORCE* for the production of one metric tonne of steel, bitumen, cement, aggregates, concrete plant and asphalt plant. The concrete plant indicator, reported in m³ in *ECORCE*, has been converted to a mass value using a density of 2.2 tonne/m³.

Global Warming Potential (GWP)

A list of 20 pollutants has a characterization factor for GWP. All processes have values for CO_2, CH_4, N_2O and CO. CO_2 is the most important contributor to the GWP indicator. The largest CO contribution is 1.6% for the production of aggregates. Bitumen and cement have values for other pollutants, but their contribution is less than 0.1% and, as a result, missing values do not appear problematic. GWP unit indicators for six processes in *ECORCE* are shown in Figure 2.

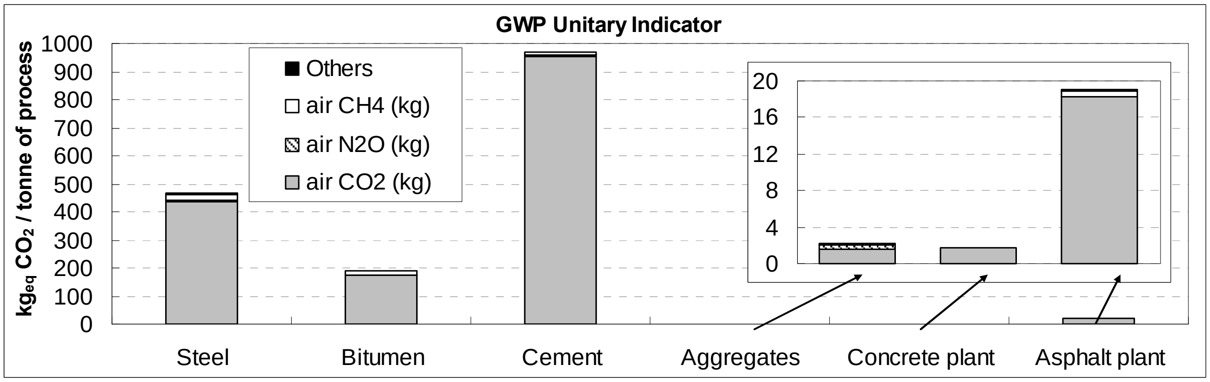

Figure 2: GWP unit indicators for six processes in *ECORCE*.

Acidification Potential (AP)

Three pollutants are included in this impact category: NO_x, SO_x and NH_3. NO_x and SO_x are the major contributors for most processes. NH_3 values are missing for steel and concrete plants. The highest AP contribution is 6% for cement. AP unit indicators for six processes in *ECORCE* are shown in Figure 3.

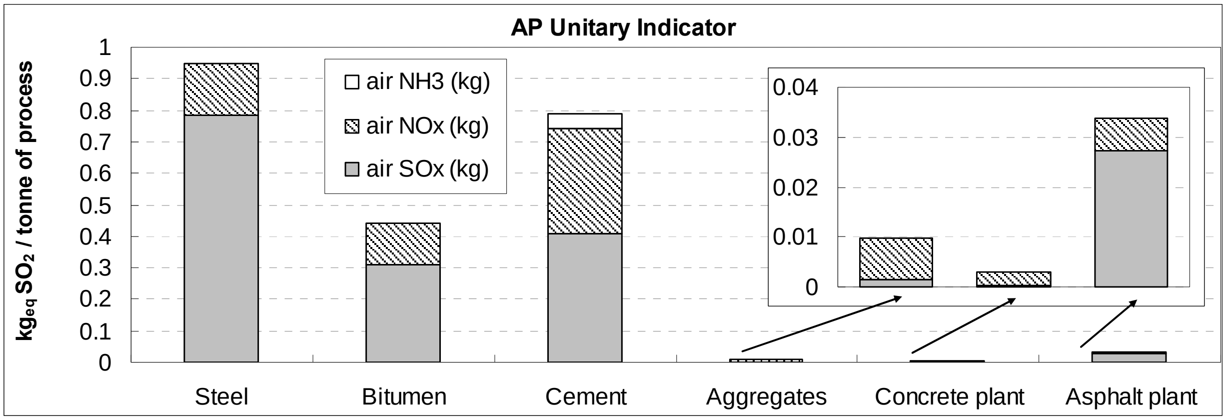

Figure 3: AP unit indicators for six processes in *ECORCE.*

Eutrophication Potential (EI)

Of the 15 pollutants identified, seven pollutants released in air or in water are significant for at least one process. NO_x in air is the most important contributor (at least 57%) to eutrophication potential for all processes. However, other pollutants can be important impact contributors, such as P_{aq}, accounting, respectively, for 18% and 25% of the steel and bitumen indicators, NH_3 and NH_4^+ in water (17% of steel indicator), chemical oxygen demand (COD) (13% of bitumen indicator), NH_3 in air (10% of cement indicator) and N_2O (19% of aggregates indicator). Table 3 shows that for some of these pollutants (NH_3, NH_4^+ in water, NH_3 in air and P_{aq}), values are missing for aggregates production and mixing plants. Special attention should therefore be given to these pollutants in developing and adapting the database, as well as in the sensitivity analysis of *ECORCE* results. EI unit indicators for six processes in *ECORCE* are shown in Figure 4.

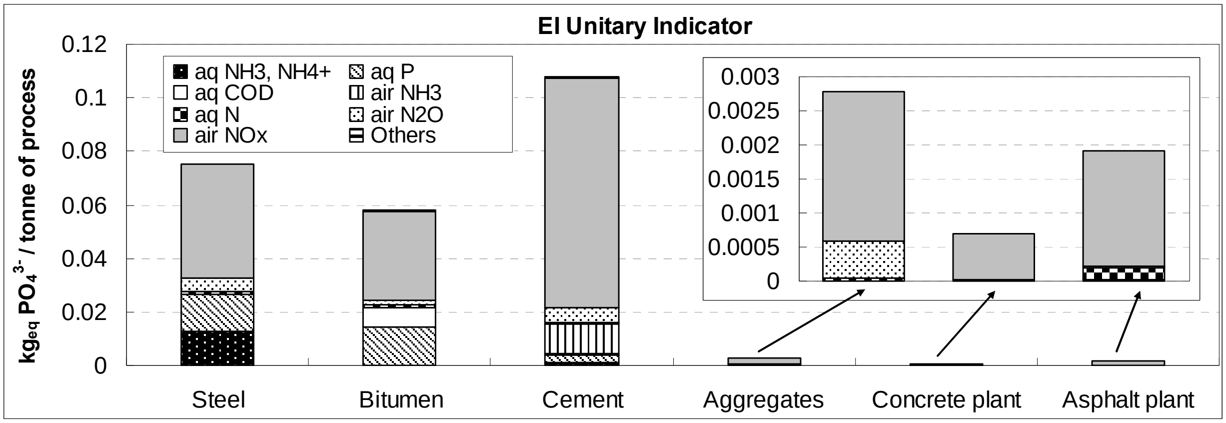

Figure 4: EI unit indicators for six processes in *ECORCE.*

Photochemical Ozone Creation Potential (POCP)

The list of pollutants contributing to this impact indicator is large. Out of the 91 pollutants in the *ECORCE* database that have a characterization factor for the POCP indicator, the contribution of six is 10% or more. The most important pollutant is not the same for all processes and values are often missing not only as a result of missing data but primarily due to pollutant aggregation in families such as Volatile Organic Compounds (VOC), Hydrocarbons (HC) and Non-Methane Gaseous Organic Compounds (NMGOC). Some chemicals families may be partly or completely included in other families. As can be seen from Table 4, at least one family is missing for all processes and more than one family can be characterized for a given process. The pollutants with individual characterization factors are responsible for the rest of the contribution to POCP.

Table 4: Contribution of Chemical Families to Processes

	HC Unspecified	VOC	NM GOC
Steel	-	-	22.0%
Bitumen	8.2%	68.2%	-
Cement	16.6%	0.1%	39.1%
Aggregates	-	47.7%	27.1%
Concrete plant	-	66.8 %	-
Asphalt plant	-	31.0%	53.4%
Machinery & transport	-	-	88.0%

In fact, according to the data sources and aggregation rules used, some pollutants that have a characterization factor may also be included in one or more groups having different characterization factors. In *ECORCE*, when an individual characterization factor was available for a pollutant, it was preferred to a family factor. For other pollutants that were not already aggregated in the LCI, they were aggregated following French standard NF P01-010 *(12).* Although further work is required to understand all the impacts of different aggregation scenarios, this study has shown that the weight of these families can often be important. Depending on aggregation rules and/or database precision, pollutants can be classified in more than one group. When developing or adapting the database, special attention should be given to aggregation rules. POCP unit indicators for six processes in *ECORCE* are shown in Figure 5.

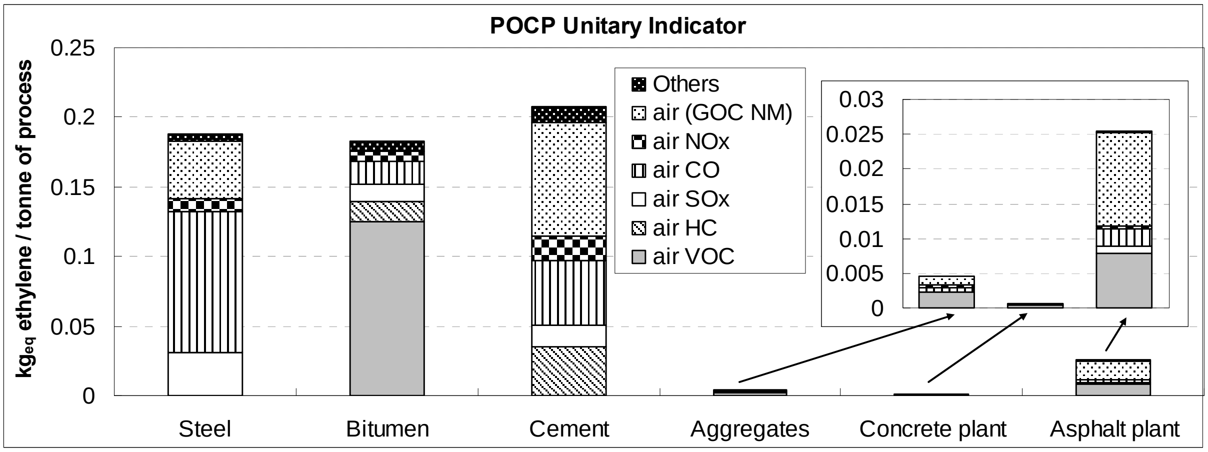

Figure 5: POCP unit indicators for six processes in *ECORCE.*

Toxicity (TP) and Ecotoxicity (EP)

These impact indicators are affected by numerous pollutants and are more difficult to analyze. As can be seen from Table 3, characterization factors for different pollutants vary by many orders of magnitude. In Figure 6, unitary indicators for toxicity and ecotoxicity are reported on a log scale to illustrate the orders of magnitude differences between processes. Pollutant contributions are not shown in this figure.

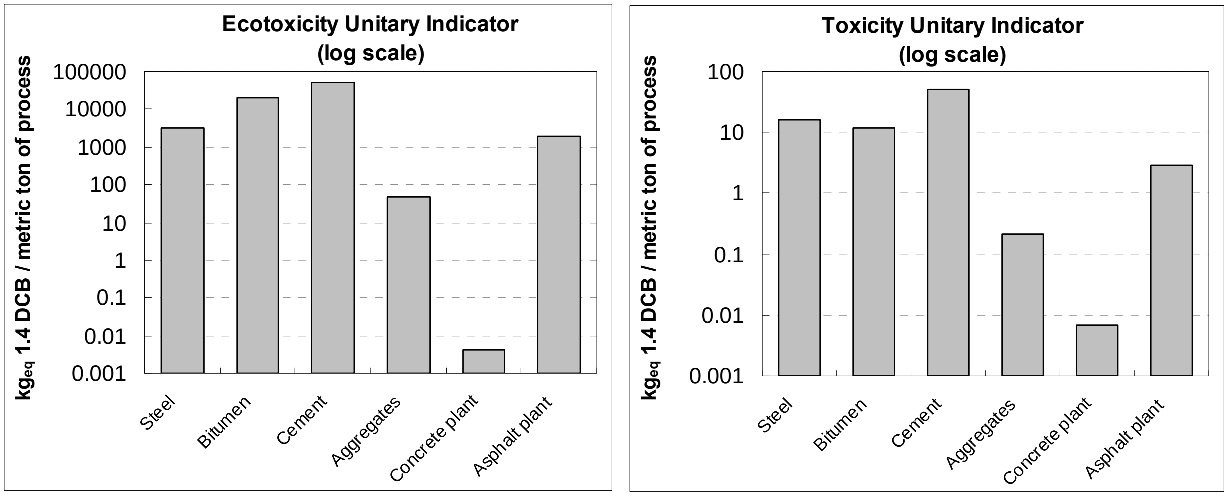

Figure 6: Toxicity and ecotoxicity unit indicators (log scale).

Very small amounts of toxic pollutants can contribute significantly to unit indicators. Differences in toxicity and ecotoxicity models in different LCIA methods are also very important. From a practical standpoint, these differences imply different classification and characterization factors, as well as different pollutant lists. For example, in *ECORCE*, vanadium often appears as the most important contributor to ecotoxicity and is also a significant contributor for toxicity. Missing values for this pollutant could therefore pose a problem. However, this pollutant is not characterized in other LCIA models such as *IMPACT 2002+* or *TRACI*.

The use of this approach for easy identification of pollutants that are important contributors to toxicity and ecotoxicity is not optimal in the context of adapting the database for international use. Pollutant inventories for these indicators are more data-poor and less reliable. Furthermore, the analysis is made more difficult by the fact that there are numerous models which vary widely and are context-sensitive. In *ECORCE*, as in other streamlined LCA tools that do not allow sensitivity analysis with different LCIA models, toxicity and ecotoxicity indicators should be treated with caution.

Synthesis of Significant Pollutants in *ECORCE*

Table 5 summarizes the most important contributors to impact indicators in *ECORCE* identified in this paper. Toxicity and ecotoxicity are excluded from this table since the approach experimented in this study was not adequate for these impact indicators. For each impact indicator, the most important contributors (> 50% of the unit indicator for at least one process) are identified in bold.

For the impact indicators GWP and AP, there are only few contributors and they are common to several LCIA models. Since these pollutants are usually documented in LCI, these indicators should not pose challenges to regional adaptation of the database.

For the eutrophication indicator, six significant pollutants have been identified and inventory data are missing for some processes in *ECORCE* database. A contribution analysis at the project level should be conducted to evaluate the impact of missing data on LCA results. A special care should be given to these pollutants when adapting the database.

For POCP indicator, there is three significant pollutants and three significant families of pollutants. Missing data in *ECORCE* database are related to the pollutant families. Special care should be given to the aggregation rules when adapting the database.

Table 5: Synthesis of Significant Contributors and Missing Data

Impact	Pollutants contributing > 10%	Processes with missing data
Global Warming Potential (GWP)	**air CO_2** air N_2O	- -
Acidification Potential (AP)	**air SO_x** **air NO_x.**	- -
Eutrophication Indicator (EI)	aq. NH_3 and NH_4^+ aq. P aq. COD air NH_3 air N_2O **air NO_x**	Aggregates, Concrete and Asphalt plants, Machinery Concrete plant Steel and Concrete plant - - -
Photochemical Ozone Creation Potential (POCP)	**air CO** air NO_x air SO_x **air VOC (family)** air HC (family) **air NM GOC (family)**	- - - Steel Steel and Concrete plant Bitumen and Concrete plant

CONCLUSIONS

This paper describes principles involved in adapting the *ECORCE* database for application in a country other than France. The data available have been published in various journals and conference proceedings, which ensure that they underwent a comprehensive critical review process and cover the full range of software application fields. Recent collaborative work between Ifsttar and the MTQ laid down the groundwork for an approach aimed at facilitating the adaptation of the pavement LCA tool *ECORCE* to other countries. This approach identifies the pollutants that are significant contributors to impact indicators and can be applied to other tools. However, the list and results presented in this paper apply only to the *ECORCE* database and impact indicators.

Several aspects must be considered when adapting environmental data in a pavement LCA tool for use in other countries. In addition to the fact that the data must be representative of the regional and technological contexts, the equivalence of system boundaries must be verified. Appropriate sources of energy and electricity grid mix must be selected. Various databases exist, with varying formats, levels of data completeness, aggregation rules, etc., and which comprise inventories that can include hundreds of pollutants. The approach presented in this paper simplifies the analysis of such inventories for regional adaptation of streamlined LCA tools such as *ECORCE*.

The contribution of the *ECORCE* pollutants inventory to six impact indicators was assessed. A short list of pollutants that contribute significantly to GWP, acidification and eutrophication potential was identified. For POCP, this list of significant pollutants includes chemical families such as VOC, HC and NM GOC for which aggregation rules used in inventories should be carefully examined. Toxicity and ecotoxicity indicators have very complex and variable models and their contributors are characterized by more or less reliable data. Mean contributors in *ECORCE* have been identified, but the approach appears too simple to be optimal and more work is needed to establish a better understanding of contributors to these impacts indicators.

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Papers from the International Symposium on Pavement LCA 2014
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The International Symposium on Pavement LCA 2014 was held on October 14-16, 2014 in Davis, California. The symposium website with information regarding all activities over the three days is www.ucprc.ucdavis.edu/LCA2014/. This symposium is the third in a series that began with a Pavement Life Cycle Assessment Workshop held in Davis, California in May, 2010 (www.ucprc.ucdavis.edu/p-lca/), and was followed by the International Symposium on Life Cycle Assessment and Construction, Civil Engineering and Buildings held in Nantes, France in July, 2012 (lca-construction2012.ifsttar.fr/).

The organization of this third symposium included invited presentations on current topics in pavement LCA followed by breakout sessions in which symposium participants discussed issues and questions posed by the invited presentations. The papers included in this volume cover a wide range of subjects regarding pavement LCA, and were reviewed by experts in both pavements and LCA. Each of these papers was also presented at poster sessions further stimulate discussion among symposium attendees.

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